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LIFE SCIENCES AND SPACE

REPORT

OF THE

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U.S. HOUSE OF REPRESENTATIVES

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PURSUANT TO

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., August 15, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics.

DEAR MR. CHAIRMAN: I am forwarding herewith for committee consideration a report, "Life Sciences and Space," prepared by Dr. Charles S. Sheldon II, Technical Director, and reviewed by other members of the professional staff. Thanks are also extended to the technical reviewers in NASA and the three armed services.

The report reflects findings of the two days of hearings held June 15 and 16 by the Special Investigating Subcommittee of this committee, and should be viewed as introductory and preliminary in nature. The strong possibility of need for further study is suggested by the number of questions raised during these hearings which it was not possible to pursue to a satisfactory conclusion at the time.

The committee views work in the life sciences connected with space as extremely important, and commends the contents of this report to the Congress and the public at large.

CHARLES F. DUCANDER,
Executive Director and Chief Counsel.

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LETTER OF SUBMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., October 4, 1960.

Hon. SAM RAYBURN,
Speaker of the House of Representatives,
Washington, D.C.

DEAR MR. SPEAKER: By direction of the Committee on Science and Astronautics, I submit the following report for the consideration of the 86th Congress.

OVERTON BROOKS, *Chairman.*

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86TH CONGRESS } HOUSE OF REPRESENTATIVES { REPORT
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LIFE SCIENCES AND SPACE

OCTOBER 4, 1960.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. BROOKS of Louisiana, from the Committee on Science and Astronautics, submitted the following

REPORT

[Pursuant to H. Res. 133, 86th Cong.]

LIFE SCIENCES AND SPACE

I. Introduction

In the eyes of most people, man's mastery of his environment extends beyond space exploration by instrumented probe to human travel through space to the Moon, other planets, and eventually outside the Solar System. Some of these efforts may be very long range, but manned flight in orbit is very close, and Project Mercury for this purpose has the highest national priority. More ambitious efforts will require considerable basic research in biology and much practical development of life support systems, work that must be started now if applied capabilities are to exist a few years hence when they will be needed.

The recent report of this committee, "The Practical Values of Space Exploration",[1] also developed that Earth-bound medicine and biology can benefit from the understanding and the experiments our space efforts will make possible, quite aside from the direct benefits to space travel per se that space medicine research will bring.

The National Aeronautics and Space Administration is charged with responsibility for carrying out the civilian part of this Nation's peaceful development of space technology. Adapted from the former National Advisory Committee for Aeronautics, NASA confronts a new, more comprehensive program with assignments extending well beyond those within the experience of the former NACA. Operating with a mandate from Congress to meet these broader challenges, NASA has had to decide where it would adapt its inherited research structure, where it would create new laboratories, where it would recommend the transfer of other agencies' existing laboratories to its direct control, and where it would rely on contracts either with other Government agencies or with private establishments. There remains the final alternative of disavowing interest in pursuing certain areas of research on the grounds that others are already doing an adequate job which meets all significant national needs. Certainly the general field of space medicine lay outside the area of primary interest of the former NACA, although some joint efforts in human factors work were carried out, and so NASA has been faced with taking some affirmative action to meet its new responsibilities in this field.

The military services have had a longer tradition of interest in the medical problems of manned flight in the air, and with the increase in speed, altitude, and other operating parameters, they have been pushed by the march of technology, or perhaps it would be better to say they have led the way, to flight conditions hardly distinguishable in certain respects from those attendant with early space flight. Some

[1] House Committee on Science and Astronautics, The Practical Values of Space Exploration (H. Rept. 2091), 86th Cong., 2d sess., July 5, 1960, 54 pp.

military laboratories and individuals would like to pursue these interests and keep in the vanguard of research in this area, for there are military implications inseparable from civilian ones in manned space flight.

The consequences of having NASA decide among several alternate possibilities, and the vested interest of military laboratories in some aspects of space medicine have made a review of these matters important to the Committee on Science and Astronautics. Accordingly, using the vehicle of the Special Investigating Subcommittee, hearings were held on June 15 and 16, 1960, to explore in an introductory way some of the reasons for interest in space medicine, the facilities and talents existing for pursuing this work, and the alternative ways of harnessing this ability to meet national goals.[2]

The committee heard the following witnesses (in order of appearance):

Dr. Clark T. Randt, Director of the Office of Life Sciences Programs, National Aeronautics and Space Administration.

Lt. Col. Richard R. Taylor, Chief, Research Division, Medical Research and Development Command, Office of the Surgeon General, Department of the Army.

Lt. Col. James B. Hartgering, Chief, Medical and Biological Sciences Branch, Life Sciences Division, Office of Chief of Research and Development, Department of the Army.

Capt. Clifford P. Phoebus, Director, Astronautical Division, Bureau of Medicine and Surgery, Department of the Navy.

Brig. Gen. Don D. Flickinger, Assistant for Bioastronautics, Headquarters, Air Research and Development Command, U.S. Air Force (accompanied by Col. Karl H. Houghton, Chief, Aerospace Medicine Division, Directorate of Professional Services, Office of the Surgeon General, Headquarters, U.S. Air Force; Col. John R. V. Dickson, Director of Development Programing, Office of Deputy Chief of Staff, Development, Headquarters, U.S. Air Force).

In its orientation, this report has concerned itself primarily with those aspects of the life sciences and space which are of direct interest to the National Aeronautics and Space Administration. It has not developed the full case for military interest in manned space flight. A very strong argument for such military interest in terms of the missions to be performed can be offered, but this has been alluded to only indirectly in this report. So long as military forces continue to be required—and no end is in sight yet—men will have to travel in person on the surface of the world, under the sea, in the air, and for the future, in space, to perform a variety of missions which cannot be delegated exclusively to automatic devices. A real capability to use space for military purposes, even though we hope this will be for protective, policing, and deterrent purposes only, will require a major and imaginative effort in bioastronautics to acquire the necessary knowledge and experience. It is doubtful whether it is within the mission of NASA to do this whole job for the military any more than it is likely that the military would be motivated to do everything that NASA might want done in connection with space biology. In summation, the point being made is that this report has been more concerned with reviewing broad categories of bioastronautics than

[2] Special Investigating Subcommittee of the House Committee on Science and Astronautics, Hearings on Space Medicine Research, June 15 and 16, 1960, 86th Cong., 2d sess. 70 pp.

with developing the military urgency for manned flight, and this omission should not be taken as lack of appreciation for the importance of this military development.

There are some scientists who have minimized the necessity for putting man into space at all, because their own interests for some years can be fulfilled by instrument packages. It is not possible with limited space to dissect all the arguments which have been made pro and con between these scientists and the advocates of manned flight. However, section II of this report does give a fairly broad listing of the needs for pursuing bioastronautics.

The questions raised by this report are asked on the assumption that there are both civil and military reasons for man in space and for other biological research in connection with space. Given the thesis that this interest is vital to both the civil and military programs, the questions are, where shall the work be done, who shall direct it and provide the funds, how shall a total and comprehensive program be planned and coordinated?

II. The Needs for Bioastronautics

It is not possible today to catalog all the potential developments in bioastronautics, for the field is still relatively new, and in common with other space activities, many of what will be the most promising and useful developments are hardly predictable. The outline which follows is merely suggestive of some of the major areas of concern.

MAN IN SPACE

Although each flows from the preceding, and divisions are not clear cut, it is possible to group the problems of manned space flight under three time-scale headings: immediate problems; long-range problems; and ultimate goals.

Short duration orbital flight

The most immediate space flight problems of the United States are those grouped under the name Project Mercury. This has been so thoroughly reported elsewhere that it is not necessary to detail what is planned.[3] Sometime close to the end of this calendar year (1960), it is hoped to give one of the seven astronauts a short ballistic flight from Cape Canaveral in a Mercury capsule boosted by a Redstone missile. Under conditions less severe than required for orbital flight, it will allow a check-out of the Mercury system, and also return useful data about such flight, including the problems of noise, vibration, acceleration, reentry, weightlessness, communications, controls, observation, rescue and recovery. The planning goal, although not a firm operational decision yet, is to launch a manned Mercury capsule into orbit before the end of 1961 using an Atlas missile. The flight program calls for three passes around the world in about 4½ hours' time, with recovery in the Atlantic near Antigua.

In one sense, Project Mercury is a very primitive beginning. The astronaut will be strapped in a form-fitting couch and will wear a

[3] House Committee on Science and Astronautics, Project Mercury—First Interim Report (H. Rept. 1228), 86th Cong., 2d sess. January 27, 1960, 78 pp.; Senate Committee on Aeronautical and Space Sciences, Project Mercury: Man-in-Space Program of the National Aeronautics and Space Administration (S. Rept. 1014), 86th Cong., 1st sess. December 1, 1959, 97 pp.

pressure suit. The flight will be programed to operate automatically and with ground control; at the same time the astronaut will be more than a passive passenger replacing an earlier test primate. He can activate in emergency the initial escape system, orient the capsule, and fire the reentry retrorockets. He will have some observation facilities including a window and periscope. Automatic telemetry from the vehicle and his body can be supplemented by voice-reported observations of performance and sensations.

To refer to Project Mercury as primitive is appropriate only in relation to the future. For the present, it constitutes one of the most ambitious undertakings of all time. It combines many different elements of our present technical ability and knowledge. Meticulous attention is being paid to the whole range of problems which must be overcome before the entire mission can be a success. Many of these relate to the reliability of the powerplant, guidance, and control, and the problems of successful reentry and recovery, together with a variety of special safety measures. On the ground, as a direct outgrowth of previous work with human factors in high performance aircraft, it has been possible to test the ability of the astronauts to withstand the acceleration and deceleration forces, some of the orientation and control problems, and the life support system with its oxygen supply. In the air it has been possible to test for a few seconds, weightlessness, by flying an aircraft in a path equivalent to a ballistic trajectory. However, the full proof of all these experiments, and man's ability to withstand all the stresses involved will come in actual flight by Redstone and then by Atlas.

It should be made very clear that it will be possible for a Mercury astronaut to look forward to a reasonable prospect for successful flight within 2 or 3 years of the time that Project Mercury was started only because of a long tradition of aeromedical research. This knowledge is close to sufficient to make possible the short-duration flight which is all that Mercury is to accomplish.

Project Dyna-Soar is the next step after Mercury from a national point of view, although it is sponsored within the Department of Defense rather than the National Aeronautics and Space Administration. Dyna-Soar also is initially intended to involve short-duration flights, suborbital at first, and later, orbital. The big difference from Mercury is that the reentry technique will involve gliding and skipping rather than blunt-nose ballistic reentry. The expectation is that a Dyna-Soar pilot could decide to land at an airport within a particular geographic region, while the Mercury astronaut fires a retrorocket over the Pacific in order to drop within a fairly long strip of water in the Atlantic.

Neither project is an end in itself, even though it should afford much valuable data regardless of the followon efforts. The reasons for sending a man on such flights are several. Our general knowledge of human behavior and reactions will be increased, including the problems of stress and of adaptability. The man will be an observer, bringing back impressions which extend beyond the record of telemetry. The man will also be a contributor to the flight, through the exercise of judgment in handling controls. In the case of Mercury, his role will be more limited than in the case of Dyna-Soar. Then beyond these reasons, what is learned through Mercury and early Dyna-Soar flights will represent a necessary step to more ambitious operations.

Longer duration flights

One can speculate on the new problems which will be encountered in preparing for longer duration flights. Some of these ideas may be changed as a result of the Mercury and Dyna-Soar experiments; otherwise, these earlier projects would lose some of their technical necessity although not necessarily their political importance.

Longer duration flights are of two categories. Some will involve just staying in orbit around the Earth longer; others will involve travel away from the Earth to visit the Moon and other planets.

Typical of the new problems are these: If man is to stay in orbit for days and weeks, he cannot sit in a pressure suit strapped to a couch the whole time. Air supply problems become more acute, and food and water problems are introduced. Radiation hazards which were tolerable in low level orbit will be more serious with prolonged exposure and with flight at greater distances from the surface of the Earth. Reliability of all components over time becomes critical. The problems of deprivation from customary stimuli, and other psychological problems may become much more acute.

Prolonged flight away from the Earth as opposed to prolonged orbital flight involves higher speed which imposes particularly acute reentry problems, as well as a longer period of acceleration. It also involves more acute guidance and orientation problems because of both the effect of distance on percentage errors, and new needs for making rendezvous with other vehicles for logistics reasons.

Circumlunar and planet observation flights will be followed by the need for making landings on alien territory, including successful survival outside the spaceship until time for return to Earth. This opens up a host of new problems, as all of these destinations involve different kinds of hostile environments which will require advance study and special solutions to the problems they present.

For example the Moon is airless for all practical purposes. The temperature varies by hundreds of degrees as between sunlight and shadow on the surface. Despite big current mapping programs, we know little enough about surface conditions other than the grossest of topographic features. We have good indirect evidence but no definitive answer as to how deep the dust may be on the surface. We do not know exactly what problems will be involved in planting a base under the surface for protection against meteors, temperature variation, and radiation; and we do not know how soon local resources can be mined to supply power, water, and oxygen.

Mars will present another set of problems. Its atmosphere is thinner than that of Earth but extends farther out from the surface. It should allow atmospheric braking by the incoming landing craft from space (perhaps first based on Deimos or Phobos). Temperature ranges will still be extreme, but the daytime summer temperature should be bearable. Some astronomers expect to find limited amounts of free water and polar icecaps spread like a hoarfrost in extreme latitudes. They also expect to find the equivalent of lichens growing in some areas. Other researchers say that the facts apparent to our instruments have been misinterpreted, and instead of carbon dioxide in the atmosphere, various nitrogen compounds, mostly noxious, explain the spectral lines interpreted as chlorophyl and the polar caps which look like frozen water.

Venus will present still other problems. No one has seen the surface because of the obscuring atmosphere. The surface temperature may be hot enough to melt lead, which would make it an uncomfortable place to build a base. There is no real proof yet whether the planet is bone dry, or whether it is enfolded in steam. At least oceans are out of the question if the temperature estimates are accurate.

Research with telescopes and other Earth-bound instruments, theoretical studies, and instrumented probes sent to these places will have to add much to our knowledge before we are really ready to land expeditions on any of them.

With some more propulsive energy, expeditions may also in time land on the larger satellites of Jupiter and Saturn, even if they are cold worlds with atmospheres of methane and ammonia.

Just as Mercury and Dyna-Soar are taking a big current effort in the space medicine field, plus building upon the essential background of previous research, so, too, will this future effort both require a current work plus building on past knowledge. When the time comes to make intensive application of basic and other past knowledge necessary to sustained space flight, results can be expected to be successful only if the basic knowledge accumulation has started long in advance, namely, now. This is the kind of study which cannot be hurried beyond a certain point, seeking discoveries which cannot be predicted as to nature or timetable. Furthermore, reliable and versatile life support systems to meet the many challenges to be faced even a decade or more hence will be possible only by work begun now on the long leadtime aspects of these systems.

The very distant future

No time scale can be applied to the most ambitious space exploration missions, because they depend upon unforeseeable discoveries about nature. Travel outside the Solar System may lie in the indefinite future thousands of years from now, or something might happen to make it a possibility within the lifetime of people now on Earth (although the odds seem against it). When sufficiently large payloads are achieved, and perhaps if photon power is made practical, one can visualize quite advanced and complicated ecological systems capable of supporting human life for generations launched on such a voyage. Space ship speeds approaching that of light would probably create a new hazard by turning the debris in space into hard radiation relative to the space ship. If this can be overcome, perhaps the Einstein equations will bring time dilation effects quite changing the biological problems of interstellar travel. So in the area of a look toward the very distant future, which might come upon us sooner than "sober" men now think, at the very least today we need theoretical studies and all the basic knowledge we can acquire.

Range of problems encountered

This brief report does not purport to detail all the areas which affect the successful accomplishment of manned space flight missions, and the listing which follows is primarily suggestive of the work entailed.

Air supply.—On a brief duration flight, although a turbocompressor as used in aircraft is out of the question, sufficient bottled oxygen can be taken along to meet needs not much more complicated than found

in submarines or high altitude aircraft and balloons. Pressure and humidity are important as well as gas composition. On longer duration space flights the problems are more complicated because weight factors make necessary some system of renewing the used air. This may involve chemicals to take out the carbon dioxide and to set free oxygen, or perhaps some type of algal cultivation may absorb the carbon dioxide and free more oxygen. Some of these systems require power and produce awkward residues of heat to be dissipated, or water. But the research in these areas of air supply involves much more. Particularly on long duration flights, trace elements of many common substances may turn out to be lethal if allowed to remain in air which must be used again and again.

Food supply.—Research must find out what dietary requirements will sustain life, efficiency, and morale, on space flights, and do so within weight limits which are quite apt to be stringent. Some of the research effort is looking toward moderately complicated ecological systems of reasonable weight and reliability which may include the use of human wastes to feed algae, which would be used to feed small crustacea, which in turn would be a major element in the human diet.

Water supply.—This is closely associated with the food supply problem. Almost no sustained flight is contemplated that does not include reprocessing of waste liquids to create potable water. The techniques may involve filtration, ion exchange, distillation, and other processes, each assessed as to its costs in weight and space and general efficacy.

Acceleration.—Acceleration and deceleration experiments have been conducted both with centrifuges programed in various ways to simulate space flights, and with rocket sleds to test extreme stresses in emergency situations. Already we have learned much about the best relation of body axis to the acceleration force, and how to apply pressures to the body to counteract the blacking out effects of high g loads. Experiments have also been made by placing the subject in a heavy metal suit looking like an instrument of medieval torture, in which the subject is completely immersed in water. A variety of experiments still lies ahead, as the cardiovascular problems involved are acute.

Spatial disorientation.—This is another area in which much research remains to be done. Men can be placed in capsules set to rotate in various ways in all three axes simultaneously. Another experimental device rotates so smoothly and imperceptibly that the subject cannot say for sure that the room in which he is placed is moving, yet experiments have demonstrated that any head movements by the subject can produce acute nausea. Such a discovery now, in ground-based research is important in at least two ways. In the first place, it raises questions whether rotating a future spaceship to provide centrifugal force equivalent to gravity is a good idea; and it suggests the need for finding out the causes of this nausea with a view to crew selection, training, and application of drugs to offset these disturbing effects. Disorientation experiments have also been carried out by placing men in liquid of specific gravity matching the human body to remove many of the normal sensory indicators. Prolonged exposure has had some fairly acute psychological and physiological consequences.

Weightlessness.—The airplane parabolic flights and the water tank experiments have given some clues to the problems of weightlessness

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as have animal experiment ballistic flights, but until Mercury orbital flight is attained, many of the conclusions must remain rather tentative. Some observers expect the effects to be generally exhilarating. Others think there will be acute problems of nausea which could be desperate for a man with jobs to perform in space, and perhaps with a helmet enclosing his head.

Radiations.—Early worry was about the effects of cosmic rays on space passengers. The seriousness of the problem would probably depend upon length of exposure. Now that the Van Allen Radiation Belts have been discovered, and Pioneer V has shown continuing problems of radiation beyond the Van Allen Belts, the radiation hazard from external sources is viewed as acute even if not insurmountable. Like most other problems connected with space flight, the solutions involve many disciplines. A greater knowledge of the Sun might give warning of solar flares so that space flights at the most dangerous times could be avoided. Much work needs to be done on shielding techniques that will be effective at a reasonable weight. Some metal shields stop part of the radiation but allow the creation of secondary radiation which is more penetrating, and hence the best shielding may be made up of multiple elements to take care of both hard and soft radiation. Perhaps the time may come when power can be supplied from a source of reasonable weight to create a force field around the spaceship with sufficient energy to divert some kinds of radiation, and do this more effectively for the weight entailed that would material shielding. Space travelers may have additional radiation problems because of use of nuclear power sources, so that designers may have to consider using fuel for shielding, or, once in space, the cabin may have to be separated by hundreds of feet from the nuclear reactor.

Meteorites.—Once viewed as a serious threat, the general feeling now is that a properly designed bumper on the space ship will vaporize most of the very small meteorites; some attention will have to be paid to the consequences of larger punctures which become a statistical possibility on long voyages. Could any radar detector and computer at reasonable weight and power give warning to permit a corrected course for the spaceship to avoid such a hazard, and then could the ship return to a flight path reaching the intended destination? The cost may be greater than the risks of collision warrant.

Social and psychological problems.—We are only at the beginning of study of the problems of one man alone in space cut off from all customary stimuli and contacts. Even with our submarine experience, we need to know more about crew composition for extended trips, if operations are to be a success. The problems of space flight in this area have hardly been touched. Several simulators are in existence in which men have been cooped up for a period ranging from days to weeks during which they both carry out the kinds of routine instrument reading and housekeeping functions which might be expected on a long space flight, and occasionally meet simulated emergencies which have been added to their problems such as some sudden change in air supply or they must make repairs to piping and electronic equipment. Experiments have been made to see the consequences of changing the length of work, rest and sleep cycles. These experiments, too, need much more attention. For all the strain which the simulators provide with their cramped quarters and absence

of outside stimuli, psychologically there is a difference from real space flight, for the men know that all they need to do is press the "panic button" and they can step back into the normal world. This is quite different from facing the hazards of ending a voyage on an alien body, or wondering whether the return trajectory will make the right approach for a safe reentry to Earth.

SPACE AS A MEDIUM FOR BIOLOGICAL RESEARCH

Manned flight is a tremendous challenge, and represents an extension of the work long under way in the military aeromedical laboratories. But putting man into space as a part of the control system of a spaceship, as a versatile supplement to instrumentation used in observation, as a repair capacity, and as a passenger, represents only one aspect of bioastronautics. Scientists also see as another whole field the exciting prospects for using space as a medium for research in the life sciences which will greatly enhance our mastery of biological and medical techniques here on Earth.

Fallout from manned space flight

There will be some benefits which come from space flight as a by-product of the major effort to accomplish manned flight. For example, the work on acceleration stresses, particularly the sudden ones associated with emergencies, may lead to the design of safer automobiles and aircraft to reduce serious injuries in accidents. Better sensing devices to detect trouble before it becomes serious or irreversible may also increase safety of Earth-bound vehicles, particularly aircraft. And better sensing devices developed to telemeter human physiological reactions may be important diagnostic tools in guarding the health of people on the surface of the Earth.

The work designed to protect men against radiation hazards in space may lead to a better appreciation of the problems of background radiation on Earth, and also lead to drugs which will reduce the deleterious effects of fall-out radiation from nuclear weapons. Indeed, one of the services is already pursuing such research on drugs with promising results.

Long space voyages may be accomplished someday with the crew spending time in some form of hibernation. This work is still at the early stages, but one can foresee that not only might this solve problems for astronauts but it might make a contribution to curing some illnesses, handling patients in long and involved operations, where hypothermia or even quick freezing of the whole body might overcome the effects of brain damage from prolonged chemically-induced anesthesia, hypoxia, and other problems.

Research on mechanical organs to substitute in space for the normal human ones could also bring benefits on Earth. One ingenious suggestion for the future is that some space explorers might have their normal breathing and digestive systems replaced by mechanical devices to allow them to overcome some of the environmental rigors of space and other worlds. If men can be converted to "cyborgs" as they have been termed, for space travel, massive failure of vital organs of men on Earth could also be the cue for use of mechanical devices to prevent death.

Biological experiments in space

In future years there will be permanently manned stations in orbit around the Earth, or based on the Moon, and supplied by rendezvous and logistic craft that can exchange crews, bring food, oxygen, and fuel, and carry needed repair parts. Some of the activity in such stations will be fundamental and applied research in biology opening exciting and vast new prospects not available on the surface of the Earth. Space will provide a more perfect vacuum than any available on Earth attainable with pumps. This will provide opportunities for new experiments on the effects of vacuums on spores, as just one example. New opportunities will obtain for discovering the harmful and beneficial results of various kinds of solar and cosmic radiation and electromagnetic fields on living cells. Perhaps more of the secrets of photosynthesis will be discovered from such research. Perhaps experimentation with genetic mutation will be provided in this new environment. The possible therapeutic effects of weightlessness are still to be explored. Although experience may show the disadvantages are greater, it is not inconceivable that in time some types of human coronary cases will find relief by being sent to a space station in free fall around the Earth. Perhaps some ingredient in the spectrum of radiation reaching a space ship will prove efficacious in treating some forms of cancer if the patient is sent up to a space station for therapy. Such speculations may prove quite unfounded, but even stranger and unexpected dividends can follow from our investment of effort in bioastronautics.

As a sidelight on developments already found in space research which have aided health, one notes that a drug developed from a missile propellant is now used to treat certain mental illnesses. New long-life, efficient valves developed for space purposes may soon be used in defective human hearts. Surgeons already use some of the space research techniques for lowering body temperature rapidly, making new operations possible.

The size and duration of experiments involving vacuums, weightlessness, and radiation fields in space will be greater than can be conducted with Earth-bound laboratory equipment, and this should result in both more discoveries and greatly speeded results.

NATURE AND ORIGIN OF LIFE

Manned space flight represents a specific application of biological knowledge, and is a means to several ends. These include making space flight more successful in order to add to the fund of general scientific knowledge, using space for commercial and political purposes, promoting the national defense, and, of course, receiving the fallout of knowledge from the technology of manned flight which can be put to Earth-bound use.

But the quest for knowledge involves more than current applications. It involves very basic questions of the nature and origin of life, the conditions under which it may appear, its evolution, and even the occurrence of sentient beings, of which man is one.

Space flight will throw some light on these questions simply from our increased understanding of biologic processes in man himself and from the experiments which can be conducted with plants, animals, and microorganisms in the space environment. Beyond this lie the

exciting possibilities of the direct discovery of life forms in environments we view as hostile.

Here on Earth, small scale experiments have created possible models of extraterrestrial environments to see whether any of our life forms can adapt to much more rigorous conditions. Some can. But we have still to find out whether there is anything we could call native life on the Moon or any planet other than Earth in the Solar System. The odds are against finding sentient beings on any other body in our Solar System if the life forms depend upon the chemicals and temperature ranges required by higher organisms here on Earth. It would be purely speculative today to attempt to answer whether any other chemical basis exists for life in this Solar System, and even more hypothetical to speculate about other organizational patterns of matter or energy that could result in something we could call beings, capable of "thought".

The possibility of adaptability of the most rugged of Earth life forms to new environments is considered serious enough that both the United States and the Soviet Union are supposed to have taken steps to insure that any payload which may impact on the Moon, the most immediate target, is completely sterile so that later manned expeditions landing there will not be misled in their conclusions from any traces of life which they may find. Such contamination, if it did survive, could conceivably spread very rapidly.

Whether life is or is not found on another body in space, important questions can receive new tests and further elaboration. Does life appear spontaneously, given the right environment? Did life appear from some other place to be carried to several worlds either by natural forces, or by cosmic travelers of the past? Will the presence or absence of life on other planets of the Solar System give us any clues to the larger cosmological questions of life and its stage of development elsewhere in the galaxy? One cannot insist that such questions involve immediate practical applications, but philosophically they are important, and history has shown that men usually make use of the knowledge which is acquired, in ways viewed important by our kind.

Project Ozma

Although biological research per se is not involved in every aspect of the search for sentient life elsewhere in the universe, some of these related projects are tied organizationally with the life sciences in our national space effort. Project Ozma is already underway. This involves a certain percentage of the operating time with the big, new radio telescope at Green Bank, W. Va. Tuning in on the wavelength of hydrogen emissions, considered a possible frequency for long-range communication, the telescope has been pointed toward several relatively close stars whose characteristics are similar enough to those of our Sun as perhaps to have planets like those in our system. Amid the general flow of natural signals or "noise" from space, the scientists are listening for any possible pattern of signals which might represent an attempt to send meaningful information. To no one's surprise, no intelligent signals have been received so far, but in the very distant future, if we did make direct contact with intelligent life, we might feel pretty foolish if we had not even listened in for signals when it was within our capability to do so. This is more than just a problem for the physicists. The biologists, the semantic experts, the psychologists,

and others become involved in considering how utterly alien life forms might send signals, and how meaningful messages might be exchanged without a prearranged code. Cipher experts and computers are required, too, but theoretical consideration of the possibilities by specialists in several disciplines seems a desirable precurser of any big processing effort before too glibly applying human logic rules to incoming data.

Indeed, this relatively low-effort research is an excellent example of needed interdisciplinary cooperation. The cosmologist and astrophysicist must determine in the first place when and where other planets may be formed. The geologist and paleontologist must project their thoughts outward to speculate on the rates and forms of evolution which might occur on the more favored planets of other systems. The biochemist and biophysicist must consider how life gets its start, and whether this is a rare accident, or a common and continuing process. They also must consider whether this occurs on the basis of carbon, oxygen, hydrogen, and nitrogen, plus calcium, phosphorus, sulfur, and trace elements, all within a narrow range of temperature, or whether other possibilities exist. Could silicon substitute for carbon? Could quite different combinations give us life at very different temperatures and pressures? The historian, the anthropologist, and the sociologist must consider in more general terms how civilization develops. The philosopher might consider the ends other societies would seek. These questions multiply almost endlessly, and in a way it is at rather a late stage that the marvels of radio astronomy come into the picture to listen for actual signals, even though radio astronomy is one of the best new tools for pursuing basic cosmological research.

Other searches for extraterrestrial life

Chemical analysis of meteorites found on Earth may give clews to the possible existence of life in other environments. Indeed, one recent report was that certain chemicals which precede the appearance of living matter have been found during analysis of a meteorite.

Spectroscopic analysis through telescopes has given us much of our knowledge of the distribution of elements throughout the universe. It has also been used to search out traces of organic compounds in the light reflected from nearby planets.

Experiments in the life sciences will become even bolder in the near future, and will require very close cooperation between the technologists who build space vehicles and the biologists. During this decade, we should have space probes capable of entering the atmospheres of Mars and Venus. How should they scoop up and preserve samples for analysis back on Earth of any microbial content? Will we, or should we return such samples to our laboratories, or should we develop automatic processing facilities in the space ship which will telemeter the results back to Earth?

If a visitor approached Earth, how much could he learn of life forms and level of development while he was still in orbit? Without telescopes, certainly most manmade features are not very impressive. Even so, a close approach to Mars will tell us much more than we can judge at our present distance.

A very big challenge will be presented by the first soft landing vehicles which also may appear during this decade to reach the Moon,

Mars, and Venus. How can the engineers and biologists work together to design devices to find possible life any of these places? Something like a core sampling device landed on Earth to analyze one piece of surface perhaps would be very exciting to a visitor, but still would not tell him much about higher life forms. Therefore, our knowledge of other worlds by this means may be limited, too. The mobile, television-directed exploration vehicle might tell more, if it was lucky in its landing place, but without lots of tests, the knowledge might be marginal. Probably only manned expeditions with mobility on or near the surface will allow the full pursuit of whatever exciting initial discoveries the instrumented probes may turn up. It should be evident that years of research and development will be required to prepare for these several phases of life sciences research in space if the results are to be maximized.

Just as the results of study could be queered by contamination of an alien environment with bacteria or viruses from Earth, brought by an earlier probe, so, too, must study be given to the dangers, if any, of contaminating the Earth with any returned samples. The risks may be small, but they are certainly worthy of careful study to avoid the possibility of setting loose a disease which might be highly destructive of some life forms here on Earth.

It is apparent even from the limited speculation in the preceding discussion that research in space biology can be very exciting and have profound effects on both our knowledge and well-being.

III. Present Life Science Programs Relating to Space

The existing pattern of programs, resources, and facilities for space-oriented research in the life sciences need only be summarized here. For a detailed inventory, the current report of the Senate Committee on Aeronautical and Space Sciences provides an excellent accounting.[4]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

In July 1959, NASA appointed a Bioscience Advisory Committee, chaired by Dr. Seymour S. Kety, Director of the Clinical Science Laboratory of the National Institutes of Health, to study the needs for NASA research in the life sciences. It was on the basis of their report of January 25, 1960, that NASA created on March 1, 1960, its Division of Life Sciences Programs, with Dr. Clark T. Randt as Director.

The purposes of this new major division are several: (*a*) To plan and participate in future manned space flights; (*b*) to initiate a planned program of biologic experiments in the upper atmosphere and space environments; (*c*) to arrange grants and contracts in support of NASA objectives in the life sciences; and (*d*) to plan a life sciences research center. NASA wants to augment rather than replace the existing capabilities in military aerospace medical laboratories. Its representatives say that the existing laboratories will be used to the maximum extent possible, even though the new requirements will extend well beyond those required for atmospheric flight even in a space-equivalent environment. It is also the NASA view that the needs for space biologic research extend far beyond the interests and mission

[4] Senate Committee on Aeronautical and Space Sciences, Space Research in the Life Sciences: An Inventory of Related Programs, Resources, and Facilities (committee print), 86th Cong., 2d sess., July 15, 1960, 269 pp.

of the existing military laboratories, which are concerned primarily with human-factors work and biotechnology. NASA expects to continue to call military laboratories on problems involving man-machine integration, environmental stress tolerance, protective equipment and escape devices, life support systems, crew performance, and general public health problems including protection of ground crews.

As longer missions are undertaken, this work already underway in the military laboratories will require additional basic effort in the medical and behavioral sciences, particularly in cardiovascular physiology, respiratory physiology, metabolism and nutrition, and in neurophysiology and psychology. It is less clear from direct testimony how much of this extended effort will be assigned by NASA to these existing military laboratories and how much will be done inhouse or by contract elsewhere, although there seems to be a general pledge to use existing facilities to the full.

Biological investigations in general relating to the effects of the space environment on living organisms, the search for extraterrestrial life, both through organic chemical study and direct sampling, and contamination problems seem more likely to be reserved by NASA for its own research and for contracts and grants to universities or other nonmilitary institutions. NASA testimony showed that it is planned to devote about three-quarters of the research money in the life sciences to outside grants and contracts. Presumably this means one-quarter will be done inhouse, and the remainder will be divided among other Government laboratories and private research organizations including institutes, universities, and industry.

Life Sciences Research Facility

Particular interest centers on the proposed Life Sciences Research Facility, funds for which will probably be requested in the fiscal 1962 budget. This facility (formerly designated a "center") is to concentrate on three major disciplines: (*a*) Flight medicine and biology; (*b*) space medical and behavioral sciences; and (*c*) space biology. This part of the testimony makes clearer the division of labor with the military laboratories. What is called biotechnology, described above, is to be left largely to these existing military laboratories. Even so, it seems rather an arbitrary line between biotechnology and the work NASA refers to as basic medical and behavioral sciences. For even if in theory biotechnology draws upon the basic knowledge discovered in the primary field, it is likely in practice to be pushing so hard on this fund of knowledge that the line will be blurred, if our programs are to move with all speed.

NASA argues that it must operate a Life Sciences Research Facility if it is to maintain its own competence to direct broader programs arranged under contracts and grants. The Life Sciences Programs Division is expected to grow over the next several years to a level of 60 professionals, together with necessary supporting personnel, perhaps divided roughly 20 to each of the three major areas of concern. Although many of these men will have planning and administering duties, by also having laboratory facilities for them it is hoped to attract imaginative people of ability who understand firsthand the problems of research and who will not fall behind in their understanding of the latest developments because of their continuing contact with research.

No physical location has been chosen as yet for the new research facility. There is some argument for having it close to the National Institutes of Health and the Naval Medical Center, but it is perhaps more likely to be built near the Goddard Space Center in Beltsville, Md., which would still be relatively close to many other important organizations in the Washington area, but would be easily integrated with the other most closely related work underway at the Goddard Center.

Liaison arrangements

The Bioscience Advisory Committee was an ad hoc committee which was dissolved following the filing of its report. Its membership had been appointed not so much in terms of active participation in the space program as by outstanding reputation in their respective areas of research.

There is a continuing Special Committee on the Life Sciences which is primarily concerned with supporting Project Mercury, and includes in its membership specialists from the military services, the Atomic Energy Commission, the National Institutes of Health, and a few other appropriate groups.

A more general liaison is maintained with military interests in space medicine through the Office of Science in the Office of the Director of Defense Research and Engineering.

Informal liaison also exists with the National Science Foundation, the Public Health Service, the National Institutes of Health, the Atomic Energy Commission, and the Federal Aviation Agency.

DEPARTMENT OF THE AIR FORCE

The Air Force has the largest existing program in the general area of aerospace medicine. Something over 1,200 scientists and technicians are engaged in this work. It is their experience as they have moved into work with higher and higher performance aircraft—already in the space equivalent environment insofar as the pilots are concerned—that these laboratories must try to anticipate future needs by about 5 years if they are to have answers in time to meet operational requirements. This means that X–15 work began some time ago, and they are already deeply involved in the Dyna-Soar program, as well as having done the work required for Project Mercury. Before Project Mercury was established in NASA, the Air Force already had a complete mockup for a very similar orbital capsule.

Facilities

The Aerospace Medical Laboratory at Wright-Patterson Air Force Base, Ohio, has done much basic work in biophysics and physiology related to high altitude and acceleration. There are about 440 individuals on the staff, over half of whom are scientists. Quite a range of laboratories is available, and this organization works closely with the personnel and facilities of other divisions of the Wright Air Development Center. As explained earlier, full descriptions of all facilities, personnel, and funding are contained in the recent Senate report.

The USAF School of Aviation Medicine, Aerospace Medical Center is located at Brooks Air Force Base, Tex. This organization conducts research as well as providing education. Of nearly 300 on the staff,

two-thirds are on the scientific staff. Facilities include audiology chambers, environmental chambers, and radiation facilities.

The Aeromedical Field Laboratory is located at the Air Force Missile Development Center, Holloman Air Force Base, N. Mex. About one-third of the staff of close to 75 is made up of scientists. There are a variety of laboratory facilities of which the best known is the 35,000 high-speed rocket sled track.

Other important facilities are located at the Personnel Laboratory of Lackland Air Force Base, Tex.; the Life Sciences Directorate of the Office of Scientific Research in Washington, D.C.; the Biophysics Division of the Air Force Special Weapons Center, Kirtland Air Force Base, N. Mex.; the Operational Applications Laboratory at L. G. Hanscom Field, Mass.; the Arctic Aeromedical Laboratory, Ladd Air Force Base, Alaska; the Directorate of Air Force Bioastronautics, Ballistic Missile Division, Los Angeles, Calif.; the Human Engineering Laboratory at Griffiss Air Force Base, N.Y.; the Human Factors Branch at Edwards Air Force Base, Calif.; the Missile Test and Range Support Division at Patrick Air Force Base, Fla.; the Human Factors Office at Eglin Air Force Base, Fla.; and the Training Equipment Branch, Simulator Research Section, at Wright Patterson Air Force Base, Ohio.

DEPARTMENT OF THE NAVY

The Navy also has an active program of research and development in the life sciences closely related to aviation and space. About 700 scientists and technicians are engaged in such work. The same logic which has moved Air Force interests into problems of the space equivalent environment and beyond has also influenced Navy policy, and the two services have conducted active programs with a full exchange of data and results, and facilities have been developed in a way to be complementary rather than competitive. Thus such programs as the X–15 and Project Mercury, which are now assigned to NASA, have depended heavily upon the contributed personnel and facilities of both services. For example, the X–15 pilots wear an advanced Air Force pressure suit combining protection with ease of performing work while wearing it. Similarly, the Mercury astronauts wear an advanced Navy pressure suit combining protection with strong survival characteristics as might be required by a pilot down at sea with a delay in rescue. Both suits are based on shared knowledge, but each has been optimized for the particular role it is most likely to have to perform.

Facilities

The Aviation Medical Acceleration Laboratory at Johnsville, Pa. has a unique human centrifuge which has been a major element in the training of pilots to fly advanced craft such as the X–15, Dyna-Soar, the Mercury capsule, and many advanced airplanes, regardless of service. The handling characteristics of these vehicles can be programed into a computer linked with this centrifuge so that the pilot can "fly" a simulated mission and feel many of the stresses of actual flight without the risk of losing the craft and his own life. In the case of the X–15 alone, these tests have revealed over 50 potentially fatal situations which now will be avoided in flights with the real craft.

A wide range of more basic research studies are also pursued at the Johnsville facilities, involving acceleration, deceleration, high g loads, vibrations and oscillations. Men, animals, and biological materials can be tested, and protective devices developed. The regular staff totals about 36 persons.

The U.S. Navy School of Aviation Medicine at the U.S. Naval Aviation Medical Center, Pensacola, Fla., carries out a wide range of research activities in addition to its training work. These involve study of the stresses of acceleration and deceleration, high altitude, noise, and similar problems, and study of psychophysiology. One of the most interesting facilities is the spatial disorientation device, a room which can rotate almost imperceptibly and yet the subject of an experiment in it usually suffers acute discomfort and nausea. Some subjects adjust to its special environment, but on returning to the world outside face a readjust problem with similar symptoms of nausea. Another major program is the study of effects of cosmic and solar radiation at high altitude, and the preparation of instruments for use in such experiments. There has been much work on telemetry systems for returning biological data from space craft. Biopacks and recovery systems for men and animals sent to space are also developed here. The staff regularly assigned has about 50 members.

The Air Crew Equipment Laboratory at Philadelphia, Pa., has not only developed pressure suits used for space, but works generally on environment systems and cockpit design. About 120 personnel are assigned there of whom one-third are scientists.

Space medical capabilities exist to a substantial degree also in the Naval Medical Research Laboratory at New London, Conn., in connection with the Submarine School, the Naval Medical Research Institute at Bethesda, Md., and in the U.S. Naval Missile Center, Point Mugu, Calif. The latter facility is being expanded to meet the growing needs of the Pacific Missile Range.

Other space medicine contributions come from the U.S. Naval Research Laboratory in Washington, D. C., the Biological and Psychological Sciences Division of the Office of Naval Research in Washington, D.C., and the U.S. Naval Training Device Center, Office of Naval Research.

DEPARTMENT OF THE ARMY

The Department of the Army does not have a program in space medicine as such. In the past, however, it has made important contributions, and it has present facilities which could continue to be of assistance in a number of respects if called upon. Close to 950 personnel are active in life science programs which support aerospace activities. The Army worked with the Navy in making possible the famous flight of the monkeys Able and Baker in the nose of a Jupiter missile. Army medical officers are on loan to other national programs as a part of the tri-service effort which presently supports NASA.

Facilities

The Walter Reed Army Research Center in Washington, D.C., is pursuing an important program on the effects of total body irradiation and protective devices to minimize harm that may follow such

exposure, and already drugs that work well on animals have been found, although they do not yet leave a man free from harmful side effects which would affect his capacity to perform active work in a space ship crew even if they guard against radiation. Stress effects studies are also underway at Walter Reed.

The Army Medical Research Laboratory, Fort Knox, Ky., is conducting experiments in human perceptual abilities. The Medical Research and Nutrition Laboratory, Fitzsimons General Hospital, Denver, Colo., is doing the only fundamental research on problems of nutrition in the Department of Defense, including work with algal food sources. A number of other Army organizations also do supporting work, such as the U.S. Army Biological Warfare Laboratories, the Human Resources Research Office, the Personnel Research Branch of the Adjutant General's Office, and the activities of the Quartermaster Corps such as the Q.M. Research and Engineering Center Laboratory, and the Q.M. Food and Container Institute.

DEPARTMENT OF DEFENSE AND TRI-SERVICE ACTIVITIES

The Armed Forces Institute of Pathology is the principal tri-service organization for the study of disease. Included in its research are environment studies which are applicable to space research. These disease studies extend far beyond those caused by microorganisms to the problems of toxicity in closed environmental systems, radiation hazards, and all the human hazards that cause accidents in aircraft, and by extension, spacecraft.

Informal liaison among the three armed services in the area of the life sciences is extensive and effective, according to the principal witnesses before the committee representing such work in these services. Formal liaison is effected through the Office of the Director of Defense Research and Engineering. With his responsibilities to the Secretary of Defense for a coordinated and effective program of research and development, the Director is responsible for the following principal committees: The Defense Science Board, which ties together all the sciences; the Advisory Panel on Medical Sciences; the Advisory Panel on Psychology and Social Sciences; the Coordinating Committee on Science, which includes life science members; and finally, the NASA-DOD Space Science Committee which extends coordination both throughout the Department of Defense, and with NASA. Additional coordination is effected through the DOD-NASA Life Sciences Research Conference.

IV. Organizational Questions

The committee was impressed with the great variety of work underway in the three armed services, and with the general outline of work which NASA is interested in undertaking in fulfilling its expected responsibilities in the area of the life sciences. At the same time, there were many questions raised by the several recitals.

One of the basic questions at stake is that of duplication of activities. Does NASA plan to duplicate work already underway in military laboratories? This question was put in various forms, and the insistent answer was that there is no such intention. Seeking an independent judgment is not altogether possible although some guide-

lines are available. Going through the detailed inventory of existing activities prepared by the Senate Committee on Aeronautical and Space Sciences, one notes that a number of similar sounding activities are conducted now by the Air Force, Navy, and Army. Yet the services are generally of the opinion that they do not duplicate needlessly each other's work. Indeed, review of individual facilities of a particular service gives further indication that within a single service, there is similar sounding work listed at different installations. Actually in most cases, a very limited number of individuals is involved in many of these areas. Following different paths, taking different emphases, or using different equipment, they are tackling complex problems. It is difficult to criticize any of this work as unnecessary duplication because of the very nature of research, as it is pursued in Government laboratories, in the universities, and in other institutes and industry. With interchange of ideas through visits, correspondence, and professional meetings, work can be coordinated, and is probably often better pursued in a number of places than to try to bring all personnel together in a single or very few locations. Of course overfragmentation is possible, too.

Looking at the complex listings of projects, facilities, and personnel as presently assigned suggests that any quick, outside review does not supply enough information to test the efficacy of present arrangements. It definitely does not seem to meet the question of how NASA will fit into this existing picture. Will it merely supply funds for a more extensive program to meet growing needs, and pursue just those pieces of the program the existing laboratories can not pursue? Will it want to have a comprehensive and balanced program conducted in its own facilities so that it will keep coming back for funds, and will it hire away key people from the existing facilities? Will the present resolution not to duplicate work change once a charter is approved and some time has passed? Some of these questions are beyond final answer today regardless of the sincerity of present witnesses before the committee.

Another related question is whether the existing military facilities are being used to optimum capacity. The witnesses before the committee indicated that research men who can not think of more things to do than they are provided funds to pursue would hardly fit the normal mold. All of them have ideas of things they would like to do, even within the framework of existing facilities and senior staff. The services recognize there is a difference between their own major interests in fulfilling military missions, which presumably will involve space in the years ahead, and some of the other more basic scientific goals of NASA. Undoubtedly a number of those connected with the life sciences in the military services would be willing to expand their present research activities into new fields if additional funds were provided at no cost to present programs. Accordingly, the question remains, beyond the initial one of the risk of direct duplication between NASA and the military services, whether the national interest would be served best by assigning the new duties coming with an expanded space program to new NASA facilities, or whether work at existing laboratories should be extended. It seems unlikely that NASA can discharge its very broad responsibilities without a major support effort in the life sciences, for reasons discussed in section II of this report. But should its work be one of program formation and

funding, or should it create facilities in the life sciences? NASA has argued that it must have some facilities of its own if it is to attract the right kind of scientist supervisors, and give them the means to keep up to date with their specialties. Of course, one could argue that if interagency cooperation is so good, these men could work in military biological laboratories when not engaged in NASA administration. On the other hand, if in practice this does not work well for the civilian NASA organization, and if there is to be a truly large expansion of life sciences work anyway, then with the right guidelines, new NASA facilities need not leave military facilities idle or work unnecessarily duplicated.

So far, the questions have largely turned on expansion of activity at existing military laboratories or creation of the new NASA center. But what shall be the work done in nongovernmental laboratories? According to NASA, three-quarters of its life sciences work will be done under contract. How will this be split between military laboratories and outside facilities? When it comes to quite fundamental research, many projects may involve relatively modest sums of money and may turn out to be best undertaken at universities and nonprofit institutes. Then continuity of contracts and the problems of administration to insure a minimum of low priority work (even though basic research can not be directed or results predicted) become critical. Other research projects may tend more toward development, and require very close coordination with engineering efforts. In this area, it may develop that some industrial firms are particularly well suited to pursue these phases of the national program. Indeed, some of the major companies today are involved in the life sciences and have some fine laboratory facilities. These activities have not yet been reviewed by the committee.

One unexpected series of questions showed up during the course of the hearings. The Federal Aviation Agency is about to construct and staff major research facilities in the life sciences at Oklahoma City, Okla., as a part of its responsibility for setting standards of aircraft flight safety and performance. There is no doubt of FAA's interest in many of these problems, and the need for additional research in these areas. Considering that NASA still has responsibility for aeronautics as well as space, perhaps the real question of duplication is not so much between the armed services and NASA as it is between the FAA and NASA, if each is about to construct a new facility. At the very least, more information is needed as to the amount of joint planning which is underway and the extent to which specific safeguards have been created to avoid duplication and to share results.

V. Committee Conclusions

1. Work in the life sciences needs proportionate emphasis with development of space propulsion, guidance, control, communications, and structures, if any significant capacity for manned travel is to develop and if major discoveries in space are to be made from effects on man and other living material.

2. Particular attention should be paid to long leadtime aspects of work in the life sciences, and the relatively modest investment this entails, if we are to extract full benefit in a timely fashion from operational vehicles of the Saturn, Nova, or Rover classes, 5, 10, and 15 years from now.

3. Congressional intent should be made clear that in supporting an expanded effort in the life sciences, the executive branch is expected to carry out this expansion with adequate protection of our existing facilities and personnel against unnecessary duplication, or unused capacity which is still needed. However, the nature of much of this life sciences research is such that no single laboratory or organization should have an exclusive right to pursue these efforts if we expect maximum progress. There is room for such work to be conducted by the National Aeronautics and Space Administration, the armed services, and many other institutions. We must at the same time provide for adequate interchange of information and share the use of facilities and personnel so as to advance the national program with the greatest speed and economy. The committee bears in mind the particular responsibility which NASA has for taking the initiative in formulating a national program and in seeing that it is executed regardless of where the work is done—inhouse, in other Government laboratories, or by outside contract.

4. This committee suggests that the charter of an interdepartmental coordinating committee in the life sciences related to space be spelled out in sufficient detail that this coordinating committee can know in a timely fashion what plans there are in NASA, in the armed services, and elsewhere in Government, for projects, expansion of facilities and personnel so that it can propose best solutions from a national point of view, and do so without undue delay or complexity in administration. Perhaps the NASA representative on the interdepartmental committee would be the most logical chairman.

5. The committee recognizes a particularly acute problem in expanding life sciences work will be the availability of high caliber personnel. Careful attention should be given to necessary transfers of personnel from existing laboratories and educational institutions to new ones that such moves represent the greatest good from the national point of view, and that at the same time a conscious effort is made to expand the long-run supply of trained scientists and technicians for such work.

6. The committee is of the opinion that only the surface has been scratched in careful study of the host of problems emerging in this field, and it intends to follow these matters over a period of time in the interests of public understanding and efficiency of operations.

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